

Claims

We claim:

1. A method of reducing pendulations of cargo hoisted by cranes
5 mounted on moving platforms, comprising the steps of:
calculating an operator-input position of a boom tip of the crane;
determining a relative motion of the cargo suspended from a hoisting
cable of the crane with respect to a suspension point of the hoisting cable of the
crane;
10 providing in-plane and out-of-plane delays and gains based on the relative
motion of the cargo;
calculating a correction to a motion commanded by the operator in an
inertial frame based on the in-plane and the out-of-plane delays and gains;
calculating reference angles for a boom of the crane based on a correction
15 to the operator desired position of the boom tip and a motion of the moving
platform in order to provide damping to reduce cargo pendulation.
2. The method of claim 1, wherein the step of calculating the operator
desired position of the boom tip of the crane includes:
20 integrating operator-input rates of the boom to obtain time histories of
slew and luff angles; and
providing motion histories of the boom tip of the crane based on the time
histories of the slew and luff angles.
- 25 3. The method of claim 2, wherein operator-input rates are a slew rate
and luff rate and the motion histories are based on slew angle rates and luff angle
rates.

4. The method of claim 3, wherein the slew angle rates and the luff angle rates are converted into Cartesian coordinates to provide the motion histories of the boom tip in a stationary reference frame.
- 5 5. The method of claim 2, wherein calculating the reference angles includes calculating a reference slew angle and a reference luff angle.
6. The method of claim 5, further comprising tracking or following a desired motion of the boom tip based on the step of calculating the reference slew angle and the reference luff angle.
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7. The method of claim 6, further comprising commanding a slew motor and a luff motor to move the boom tip according to the step of calculating the references angle of the boom.
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8. The method of claim 2, wherein cargo motion is measured by a global positioning system, accelerometers, or inertial encoders that are capable of measuring angles of the hoisting cable.
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9. The method of claim 2, wherein the step of calculating the reference angles includes superimposing the correction on motion histories commanded by the operator.
10. The method of claim 1, wherein the in-plane gain and the out-of-plane gain are different.
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11. The method of claim 10, wherein the in-plane gain and the out-of-plane gain are fractions.
12. The method of claim 1, wherein the in-plane delay and the out-of-plane delay are different.
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13. The method of claim 1, wherein the motion of the platform is a motion of a ship; the ship motion is pitch, yaw, roll, heave, sway and surge.

14. The method of claim 1, wherein the motion of the platform is a moving vehicle.

15. The method of claim 1, wherein the in-plane delay and the out-of-plane delay create a damping effect.

16. The method of claim 1, further comprising calculating Cartesian coordinates of the boom tip based on the correction to the motion commanded by the operator and the operator desired position of the boom tip, wherein the step of calculating reference angles is further based on the calculated Cartesian coordinates and the motion of the moving platform.

17. A control system for reducing pendulations of cargo hoisted by cranes mounted on moving platforms, comprising:

means for calculating an operator-input position of a boom tip of the crane;

means for determining a relative motion of the cargo suspended from the hoisting cable of the crane with respect to the boom tip of the crane;

means for providing in-plane and out-of-plane delays and gains based on the relative motion of the cargo;

means for calculating a correction to a motion commanded by the operator in an inertial frame based on the in-plane and the out-of-plane delays and gains; and

means for calculating reference angles of the boom of the crane based on the correction, the operator-input position of the boom tip, and the motion of the moving platform in order to compensate and reduce cargo pendulation.

18. The control system of claim 17, wherein the means for calculating the operator-input position of the boom tip of the crane includes:

means for integrating the operator-input rates of the crane into time histories of the slew and luff angles; and

5 means for providing motion histories of the boom of the crane based on the time histories of the slew and luff angles.

19. The control system of claim 18, wherein the means for calculating the reference angles includes means for calculating a reference slew angle and a
10 reference luff angle.

20. The control system of claim 18 further comprising means for calculating reference Cartesian coordinates based on an operator desired position of the boom tip and the correction, wherein the means for calculating reference
15 angles is further based on the calculated Cartesian coordinates and a motion of the platform.

21. The control system of claim 19, further comprising means for tracking or following a desired motion of the boom based on the reference angles
20 in order to reduce the cargo pendulation.

22. An apparatus for reducing pendulations of cargo hoisted by cranes mounted on moving platforms, comprising:

a boom luff angle and slew angle motors for moving the crane;
25 a tilt sensor to measure the movement of the platform;
encoders to read in-plane and out-of-plane angles of the cargo hoisting cable and boom luff angle and slew angle of the crane; and
a controller to determine a reference position of a boom tip of the crane for reducing the cargo pendulation based on the input of the tilt sensor and
30 encoders.

23. The apparatus of claim 22, wherein the controller determines in-plane and out-of-plane gains and delays for the slew and luff angles of the crane and a correction of a motion commanded by an operator for reducing the cargo pendulation based on the in-plane and out-of-plane gains and delays.

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24. The apparatus of claim 23, wherein the controller adds operator inputs for controlling the crane with the correction and the movement of the platform in order to determine reference luff and slew angles and provides the reference luff and slew angles to a tracking control unit for controlling the boom luff angle and slew angle motors to thereby reduce the cargo pendulation.

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